THE COMBINED EFFECTS OF HEAT AND NOISE ON AUDIO VIGILANCE IN A SIMULATED HELICOPTER ENVIRONMENT

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THESIS

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by

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ABSTRACT

The purpose of this experiment was to determine the combined effect of heat and noise on subjects performing an audio vigilance task, simulating the conditions of a helicopter cockpit. The task was to correctly extract specific aircraft heading changes from tapes of random aircraft radio transmissions. Additionally, the subjects were required to track the light of a pursuit rotor to simulate manual demands of helo flight.

Experimental conditions combined three fixed levels of temperature, and three fixed levels of recorded helicopter noise.

An analysis of variance of the results indicated no significant effects of noise, temperature, or their interaction, even at the .75 level.

These results generally substantiated earlier research by others.

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I. INTRODUCTION

The effects of noise and heat on human performance have received considerable attention in the literature. Of particular interest to the military, is the area of aircraft cockpit environment.

Helicopters, constrained by design and mission requirements, operate at much lower altitudes than fixed wing aircraft; and, therefore, benefit little from the temperature decrease of higher altitudes. When operating in a tropical environment, helicopter crews tend to fly with all hatches, doors, and windows open to afford better ventilation. This results in increased overall cockpit noise level.

The helicopters, due to the addition of transmissions, rotor systems, and generally increased mechanical complexity, tend to be noisier than fixed wing aircraft for most flight conditions. A comparison by Gasaway [Ref. 1] shows this difference to be on the order of 10-15 dB.

Considerable research has been done concerning the effects of heat and noise on subjects performing vigilance tasks. Hanley and Williamson [Ref. 2] concluded noise had no effect on vigilance. Bell [Ref. 3] found no effect from heat on an audio vigilance task. Baker [Ref. 4] observed no effect from simultaneously tracking a visual target and performing an audio vigilance experiment. However, the combined effect of heat and noise on a subject assigned a manual task, and an audio vigilance task, received little attention.

The intent of the experiment was, while simulating a helicopter environment, to determine whether a significant interaction, in terms of actual cockpit performance, existed between heat and noise. Since simple bleed-air air conditioning systems for helicopters are now becoming available, and since the addition of acoustic insulation in helicopters would be relatively inexpensive, an indication of significant interaction would tend to justify further investigation into helicopter environmental design.

II. METHOD

A. EXPERIMENTAL DESIGN

It was decided that the experiment should, as much as possible, simulate actual cockpit conditions. Accordingly, the vigilance task was that of correctly identifying certain random radio instructions which were imbedded in a tape of random transmissions to various aircraft. The only question of interest was whether the identification of the cue was correct or incorrect. This simulated the actual situation the pilot faces. Further indications of reaction to the environmental conditions were not monitored, since they were not necessarily indicative of inadequate cockpit performance.

To reproduce the aircraft noise as faithfully as possible, a flight was arranged in a U. S. Army UH-1H helicopter. In-flight noise was recorded, and cockpit noise levels were measured.

The apparent loudness that is attributed to a sound varies not only with the sound pressure, but also with the frequency of the sound. This effect is taken into account to some extent for pure tones by "weighting" networks included in an instrument designed to measure sound pressure level.

The current USA Standard for Sound-Level Meters (S1.4, 1961) requires that three alternate frequency-response characteristics be provided in the instrument (See Appendix B). These three responses are obtained by weighting networks designated as A, B, and C. Responses A, B, and C

selectively discriminate against low and high frequency in accordance with certain equal loudness contours. A more detailed treatment of weighting networks may be found in [Ref. 5.]

In general, it is recommended that readings on all noises be taken with all three weighting positions. The three readings provide some indication of the frequency distribution of the noise. If the level is essentially the same on all three networks, the frequencies of the sound probably are primarily above 600 Hz. If the level is greater by several decibels on the "C" network than on the "A" and "B" networks, much of the acoustic energy is probably below 600 Hz.

Accordingly, sound level readings were taken using the "A, B, and C" weightings to give some indication of the frequency distribution.

Since it was noted that sound level was relatively constant throughout the cockpit, all readings and recordings were taken at a single point approximately 12 inches behind the pilot's head.

The temperature levels were based on personal experience in Marine AH-1G, and UH-1E helicopters in Southeast Asia, and included 95^{o}, 85^{o}, and 75^{o} F. The highest level represented an average maximum inflight temperature (ignoring higher levels during ground operation), while the lower levels were arbitrarily chosen as attainable in an air conditioned cockpit (based on experience with air conditioned AH-1G aircraft).

Although military helicopter pilots frequently spend six to eight hours per day in the cockpit, experimental runs of that duration were not feasible. Accordingly, a sequence of three twenty minute runs was employed for each temperature.

Light helicopters require constant manual control inputs to maintain stable flight. To simulate this requirement, a photoelectric pursuit rotor device was utilized. This device was utilized only as a "job", not as any type of dependent variable. An offset triangle was used for the track. Since the center of the triangle did not coincide with the center of the rotating disk, the resulting movement rate of the "target" varied with its position on the triangle. An additional "off target" indication was devised by incorporating a small flashlight bulb in the circuit, and setting it to illuminate when the photocell in the wand indicated an "off target" condition. The purpose of this bulb was simply to make it easier for the subjects to recognize an off-target situation, and, thereby avoid allowing the wand to stray frequently, which would defeat the purpose of the entire pursuit rotor task.

The experiment was performed in an acoustic, temperature controlled chamber. The background helicopter noise was amplified, and played through a speaker located approximately 12 inches behind the subject's head.

Temperature was controlled by adjusting the thermostat in the chamber heating system, and this temperature was checked on every run by recording wet/dry bulb reading.

Humidity was not controllable, but it remained relatively constant for a given temperature setting. Wet/dry bulb readings showed average relative humidity readings of 47%, 41%, and 35%, for dry bulb temperatures of

75^{o}, 85^{o}, and 95^{o} F. respectively. Actual readings were all within plus or minus two percent (relative humidity) of the average.

Globe temperature was identical to dry bulb, indicating no radiant energy. Air movement was negligible.

It was decided to specify clothing simply as light (T-shirt, slacks) since actual apparel varies greatly with individuals.

A total of nine "control" tapes were prepared by recording a random sequence of simulated aircraft radio transmissions. A transmission was not necessarily related to any previous one. Within each tape of approximately twenty minutes, were five randomly spaced cues. A cue consisted of a heading change instruction to the subject's specific aircraft. Each tape included other instructions to the subject's aircraft; however, these inputs were not used as cues. By utilizing nine tapes, no subject heard the same tape more than once.

The response apparatus had to provide for digitally selecting headings which could be externally monitored. It was also thought desireable to use actual cockpit equipment, if possible, to enhance the realism. A military TACAN (an air navigation radio) control panel was remoted to a digital, lighted numeral display outside the chamber. Thus, the experimenter could easily monitor a cue detection, as well as determine whether it was correct.

Since the TACAN panel was limited to settings between "00" and "129", all cues were within this range.

Noise levels for the experiment were assigned beginning with the maximum observed value using the "C" weighting, 116 dB, then decreasing

-- first to the lowest recorded level on the "C" scale (aircraft climbing, low airspeed), 110 dB, and finally to an intermediate recorded level on the "B" scale, 105 dB. Since the "B" weighting represents overall noise level, less frequencies below approximately 400 Hz, it was thought that such a level would be obtainable with the proper acoustic engineering.

It was decided that a headset, rather than a flight helmet, would be used. This was done since each helmet is individually fitted; hence, attenuation varies with fit and helmet type. By utilizing a common headset for all subjects, this factor was eliminated. The particular headset used was subjectively considered to provide slightly more attenuation than a typical pilot's flight helmet. The volume was continuously adjustable by the subject, as it would be in an aircraft.

The experiment presented nine conditions (three temperatures by three noise levels), all fixed, in three sets of three runs each. Within a sequence of three twenty minute tapes, the subjects were allowed 3-5 minute breaks between tapes (to allow for tape rewind, and noise level adjustment).

The order of presentation of sound level for a given temperature was varied for each subject to avoid data bias.

Conditions held constant during a given run were temperature, noise level, and pursuit rotor RPM (set at 10 RPM throughout the experiment). Each tape contained five cues.

B. APPARATUS

The inflight noise was recorded on a Sony model TC-124 tape recorder. Noise level was measured using the General Radio model 1565-B Sound

Level Meter. Inflight noise was reproduced using the same Sony recorder feeding an Altec-Lansing 324-B, 35-Watt amplifier, which, in turn, drove a 12 inch U. S. Navy General Purpose loudspeaker.

The control tapes were played on a Sony model TC-123 tape recorder, which powered a set of stereo headphones bearing no identification.

The acoustic chamber was manufactured by the Industrial Acoustic Corporation, and measured 6 by 6 1/2 by 6 1/2 feet. The chamber was essentially soundproof, and temperature was thermostatically controlled.

The small flashlight bulb was powered by a 6 volt dry cell battery, and its circuit utilized existing jacks in the pursuit rotor device. The Photoelectric Rotor was a Lafayette Instruments model 2203E, utilizing a triangular pattern on the glass template.

Wet/dry bulb readings were taken with a Bendix battery powered psychrometer.

The digital, lighted numeral display was locally produced, as was the sheet metal stand for the TACAN control box. This stand suspended the box at an angle of 30° from the horizontal for easier operation.

C. SUBJECTS

The subject field consisted of 6 males, ranging in age from 26 to 37 years, with a mean age of 30.3. Four were students at the Naval Postgraduate School, and all were active duty military officers. Five were military pilots, and one was a Naval Flight Officer. They were all familiar

with the type transmissions on the tapes. All had been in the local area at least 6 months, so acclimatization was considered similar.

D. PROCEDURE

On a given day only one temperature was used (due to the time required for the chamber to stabilize at any given temperature setting). Each subject was shown the equipment, and then read a set of written instructions (see Appendix A). The subject was then seated facing the pursuit rotor with the headset in place. The experimenter would bring the background noise level up to the desired setting, and then give the subject a "thumbs up" signal; at which point the subject started the control tape by turning on the recorder. At the same time he started to track the target on the pursuit rotor with the wand. The experimenter then monitoried the lighted numeral display outside the chamber. An indication was manually recorded for each cue response (aircraft heading), whether correct, incorrect, or omitted. No time limit was imposed for omissions -- the succeeding cue response indicated whether an omission had been made.

When the tape was complete, the subject was allowed a 3-5 minute break while the next tape was prepared. Three tapes, corresponding to the three sound levels, were played on a given day (one temperature). The procedure was repeated for the remaining two temperatures on different days. The sequence of temperatures for a given subject was governed by his availability, but was generally one of increasing temperatures.

Subjects were never told how many cues were in each tape.

III. DISCUSSION OF RESULTS

The number of correctly selected aircraft headings (cues) for each tape, and for a given temperature, noise level, and subject, formed the data. These were analyzed with a 3 x 3 repeated measures analysis of variance, but there were no significant effects on performance from temperature, noise level, or their interaction, even at the .75 level. (See Table I)

TABLE I

ANALYSIS OF VARIANCE, VIGILANCE TASK RESPONSES

SOURCE	DF	MS	F	p
NOISE LEVEL (N)	2	0.0740	0.626	NS
TEMPERATURE (T)	2	0.0740	1.429	NS
SUBJECTS (S)	5	0.0741		
N x T	4	0.0185	0.294	NS
N x S	10	0.1183		
T x S	10	0.0519		
ERROR (N x T x S)	20	0.0630		
TOTAL	53			

Recorded data showed "A" cockpit noise level readings were an average of 15.25 dB below the "C" readings. "B" readings averaged 10.5 dB

below the "C" readings. All measured dB readings were referenced to 20 micronewtons per square meter. An inspection of Appendix B in conjunction with the above data indicated considerable noise below 600 Hz (C-A); and, additionally, much of that was below 300 Hz (C-B). This was considered significant, since the human hearing threshold is higher at these lower frequencies, and so is the body's tolerance to them. This frequency distribution, then, may have been a contributing factor to the very low error rate observed in the experiment. Broadbent [Ref. 6], in a related experiment, reported significantly more errors for noise in the "above 2000 Hz" range, utilizing a 100 dB noise level.

There were only four errors in 270 cue presentations, and two of those were made by the same subject. Of the four, only one was an omissive error; the other three were incorrect responses. There were no false alarms. In this experiment, the subjects were not able to ask for the heading to be repeated, as they could in an operational situation. Hence, in actual practice, the subjects would have asked for clarification, and possibly eliminated the three incorrect responses.

An overall error rate of 0.0148 errors per trial was recorded. Subjectively, this seemed low, indicating that either the audio monitoring task was not sufficiently difficult to show appreciable degradation from outside influences, or that these influences had no effect.

Since the object of the experiment was to detect any significant degradation of performance of a <u>realistic</u> cockpit task, substitution of a

more difficult, but less realistic task was considered inappropriate. For this reason, additional testing procedures, which might have shown degradation of some task, were not used. For example, recording time-on-target for the pursuit rotor, or measuring the time from cue presentation to response may have given indications of significant heat-noise effects. However, since there was no indication that these measurements were related to degradation of actual cockpit functions, they were not considered appropriate. If the task of interest had been response time oriented, these measures may have been considered. Most cockpit tasks are not of this type -- at least for helicopters.

It was also noted that several other factors were not present in this experiment which may have influenced the results. For example, vibration, an important factor in any helicopter, was absent. Also missing were intra-aircraft (ICS) communications, additional radios broadcasting simultaneously, external factors (enemy fire, bad weather), aircraft mechanical problems, etc. A truly comprehensive experiment of that type was beyond the scope of existing resources.

IV. SUMMARY AND CONCLUSIONS

The results of the experiment indicated no significant effects from the various levels of temperature and noise level.

The low error rate of 0.0148 errors per trial may have been even lower if the subjects had been allowed to ask for confirmation of headings.

Improvements to the experiment should incorporate longer (more realistic) runs, and, if possible, vibration.

The results tended to coincide with previous research in that no effect on vigilance was noted with rising temperature and noise level.

The rough frequency analysis using the "A, B, and C" weightings indicated a considerable amount of the noise was in the "less-than-600 Hz" range. Since the "A" weighting is the best simulation of human frequency response, and using actual data from the experiment; an overall (C weighting) sound level of 116 dB in the cockpit was <u>perceived</u> by the pilot (A weighting) as 100 dB.

It was hypothesized that this preponderance of low frequencies in helicopter noise, and the human ear's tendency to discount such frequencies, may be an important reason for the apparent lack of effect of helicopter noise on vigilance.

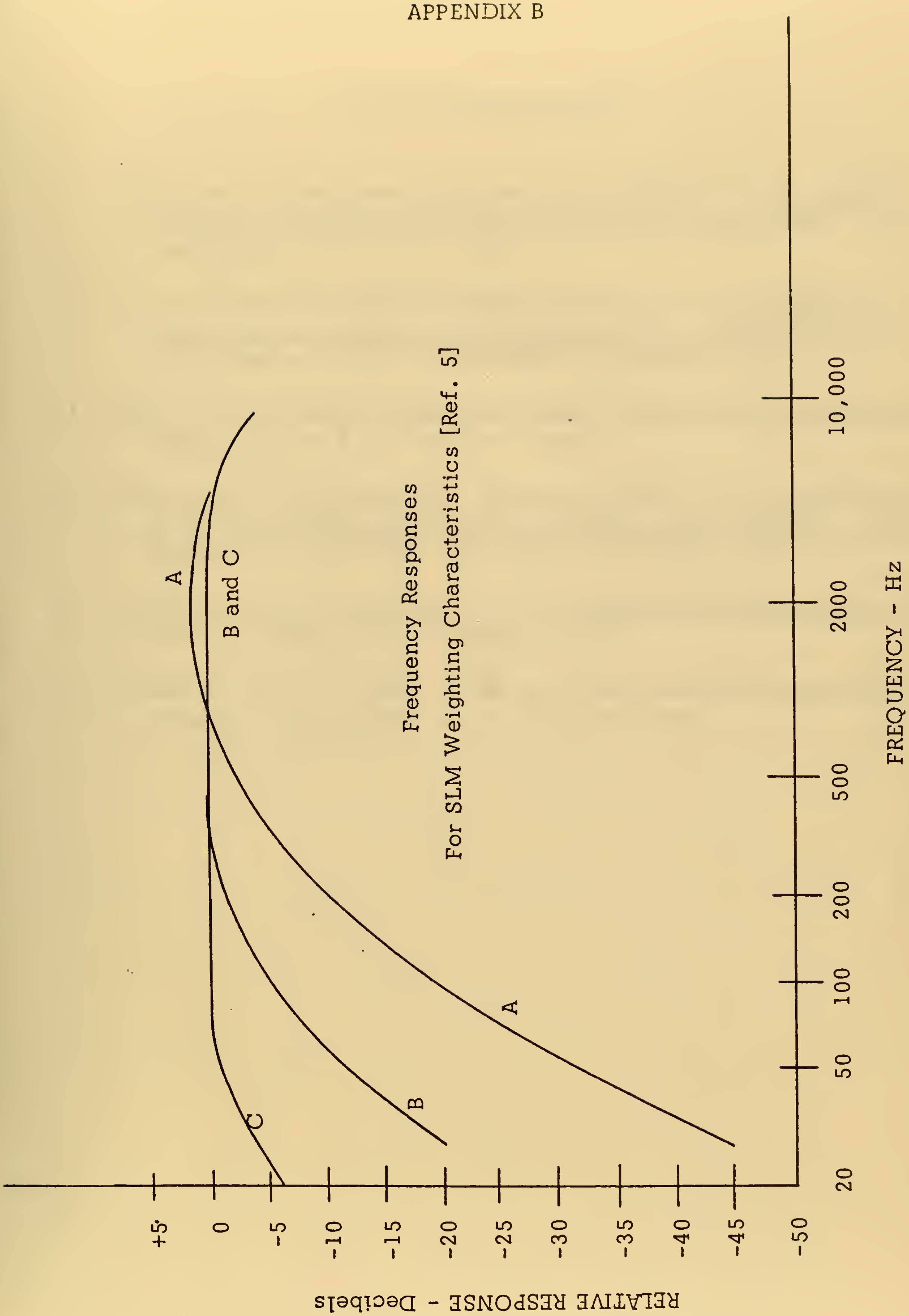
APPENDIX A

INSTRUCTIONS TO SUBJECTS

This experiment is designed to simulate the heat and noise present in a helicopter cockpit. You are the pilot of ACME 13 on an unspecified mission in a combat environment. You are being controlled by "Dash Control" which is broadcasting on several frequencies simultaneously, so only "Control" will be heard by you. You have no microphone for this experiment, so no oral response of any kind is required.

In the course of the assorted transmissions, each control tape contains several cues to which you must respond. These are heading changes. You may receive other instructions -- altitude changes, artillery warnings, etc. -- but only respond to heading changes. Upon receiving a heading change directed to your aircraft, respond by dialing the TACAN control box to the setting corresponding to the new heading. All headings will be between "00" and "129" which are the limits of the control box. To simulate the constant manual attention necessary for helo flight control, you will be asked to maintain the tip of the wand on the white dot as it moves around the box on the table. If you get off target, the small light will come on. Try to keep the light off. When you hear "End of control tape # ()", please turn off the recorder and stand by.

On a given day, three tapes will be played while operating with three background noise levels, all at the same temperature. On succeeding days, the procedure will be repeated using different temperatures.



Frequency Responses
For SLM Weighting Characteristics [Ref. 5]

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